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14. ABSTRACT

A new promising way to significantly improve computational efficiency of neurobiological network simulations is to design a neuronal model in the form of difference equations that generates neuronal states in discrete moments of time. In this approach, time step can be made comparable with the duration of action potential (a spike) and capture correctly dynamics of the intrinsic and input-responsive firing patterns. We propose to use modern DSP ideas to develop new efficient approaches to the design of such discrete-time models for studies of large-scale neuronal network activity.

15. SUBJECT TERMS

Map-based neuronal model, Discrete time spiking dynamics, Synapses, Neurons, Neurobiological Networks

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Nonlinear Maps for Design of Discrete-Time Models of Neuronal Network Dynamics

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During this one-month period PI initiated search for a postdoc candidate and started to work on the Task 1 of the research plan.

Postdoc. The research plan assumes part-time involvement (50%) of a postdoc, which have experience with neuronal network simulations using standard conductance-based models and analysis of nonlinear dynamics so he/she can clearly understand requirements for the map-based model design. The research of network dynamics utilizing the conductance-based models will be done in collaboration Dr. M. Bazhenov who will support the remaining 50% of postdoc time. Our project will be focused on the design of corresponding map-based models. I had a meeting with Dr M. Bazhenov where we have prepared advertisement for search of suitable candidate and posted it in several forum groups related to computational neurobiology.

Task 1. Meanwhile I started to explore various ideas for potential improvement computational efficiency and usability of one-dimensional map capturing fast dynamics of Na+ and K+ pumps responsible for generation of action potential (spike). This map is of the form

$$x_{n+1} = f_\alpha(x_n, y),$$

where x_n is a dynamical variable and function $f_\alpha(..)$ is a piecewise nonlinear function containing three segments. In the original form the function is

$$f_\alpha(x_n, y) = \begin{cases} \dfrac{\alpha}{1 - x_n} + y, & x_n \leq 0, \\ \alpha + y, & 0 < x_n < \alpha + y \text{ and } x_{n-1} \leq 0, \\ -1, & x_n \geq \alpha + y \text{ or } x_{n-1} > 0, \end{cases}$$

where variable x_{n-1} is used to define a condition that prevents system to remain at the top of the spike for more than one iteration. Without this condition the trajectory can stay on the top during the increasing values of slow current variable y. As a potential simplification of the original spiking model, I consider a new form of function written as

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$$f_\alpha(x_n, y) = \begin{cases} \dfrac{\alpha}{1 - x_n} + y, & x_n \leq -0.5, \\ 1, & -0.5 < x_n < 1, \\ -1, & x_n \geq 1. \end{cases}$$

In this case a gap (-0.5, 1) and a fixed value at the top of the spike excludes repetitive iteration on the top of the spike for a very large range of fluctuations of variable y. It also provides a consistent shape of individual spikes.

At the next steps of the study, I will consider the effects of the gap on the dynamics of spiking patterns activity.